Wind power R and D routes - Danish and European perspectives

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Wind Power R&D Routes
Danish and European Perspectives

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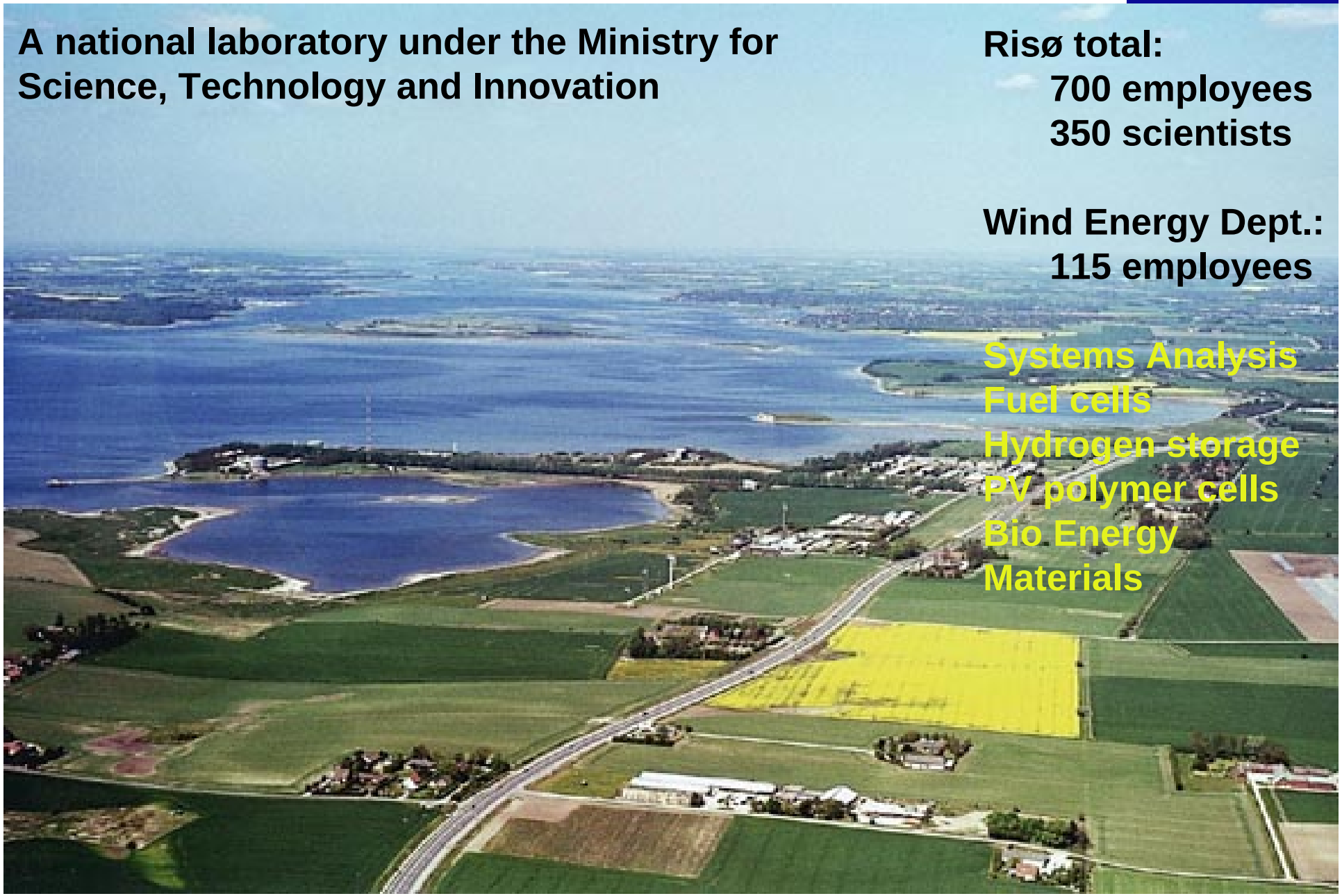
Risø National Laboratory
Wind Energy Department
Denmark

Risø National Laboratory



A national laboratory under the Ministry for Science, Technology and Innovation

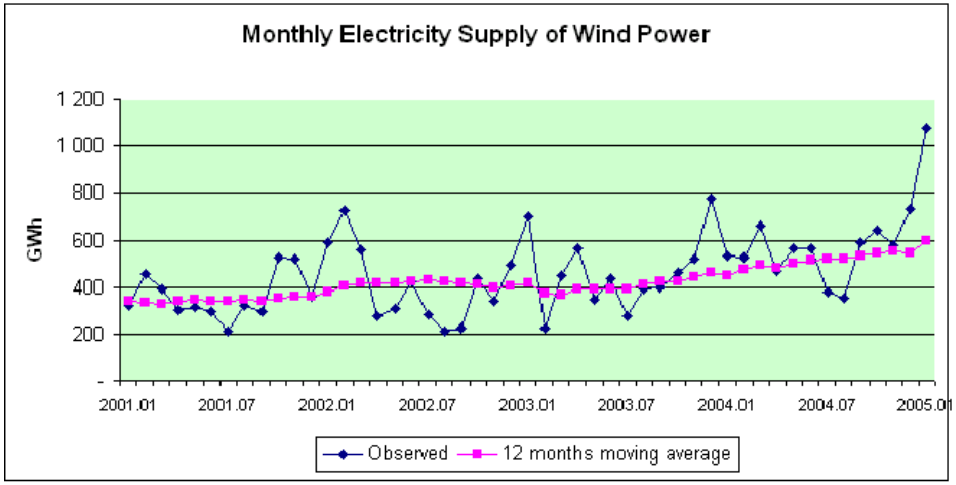
Risø total:
700 employees
350 scientists

Wind Energy Dept.:
115 employees

Systems Analysis
Fuel cells
Hydrogen storage
PV polymer cells
Bio Energy
Materials

Wind power development in Denmark

Denmark has >20% electric power supply from wind



January 2005 – 1076 GWH ~ 32% of total demand
(41 % in western Denmark)

Offshore impact
2005 = 423 MW = 4,6%
2009 = 823 MW = 9,4%

Vision: 50% of power supply by 2025

Onshore market: 100 MW per annum

Offshore market: 140 MW per annum (1 wind farm per 2 years)

Danish Research Consortium for Wind Energy

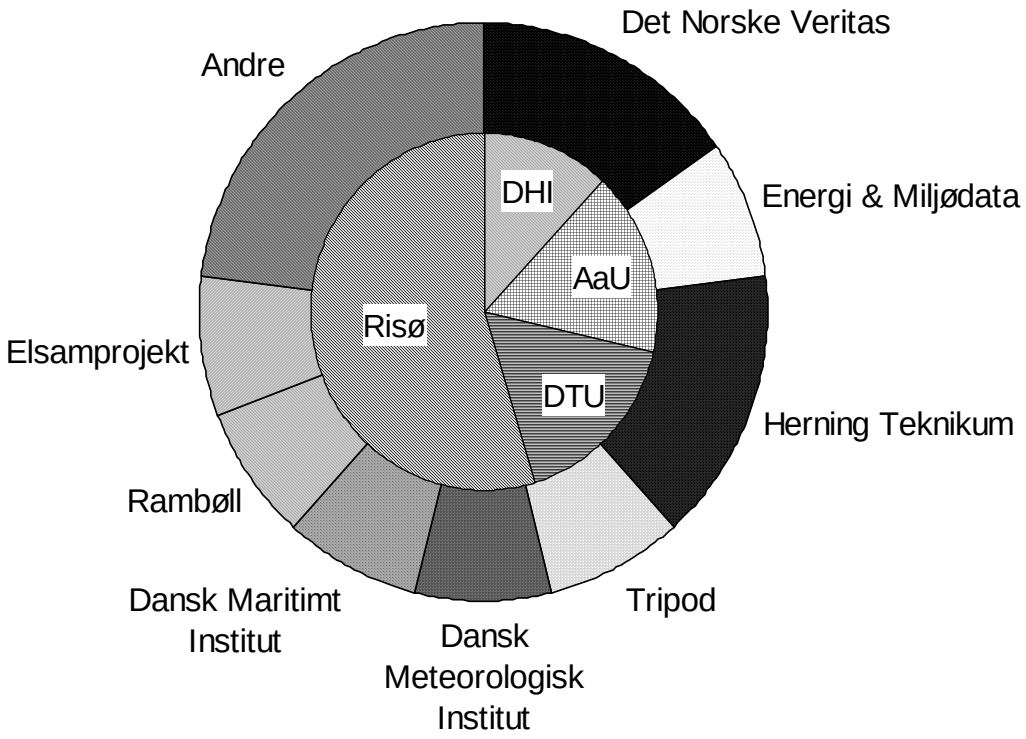
Strategic Partnership for R&D, education and research-based services

Coordinator:

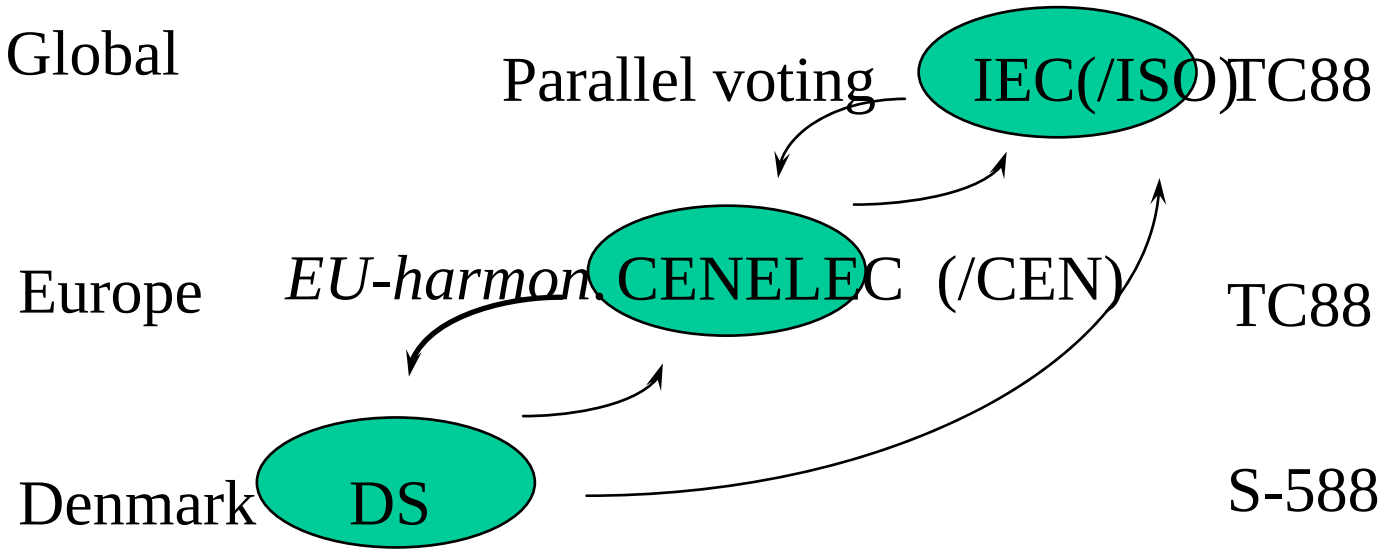
- Risø National Laboratory - Wind Energy Department

Partners:

- Technical University of Denmark (DTU)
- Ålborg University (AAU)
- DHI Water and Environment



Standardisation
Denmark, CENELEC and IEC TC88



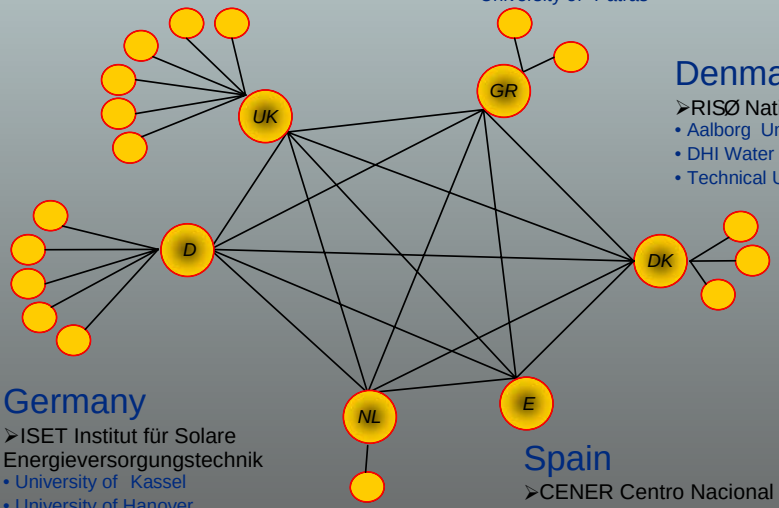
European Academy of Wind Energy

The Network

United Kingdom
➢Strathclyde University
- Durham University
- Manchester University
- CCLRC
- University of Surrey
- Queen Mary College, University of London
- Manchester Metropolitan University
- Loughborough University

Greece
➢CRES Centre for Renewable Energy Sources
- Technical University of Athens
- University of Patras

Denmark
➢RISØ National Laboratory
- Aalborg University
- DHI Water & Environment
- Technical University of Denmark



Germany
➢ISET Institut für Solare Energieversorgungstechnik
- University of Kassel
- University of Hanover
- University of Oldenburg
- University of Magdeburg
- University of Stuttgart

Spain
➢CENER Centro Nacional de Energias Renovables

Netherlands
➢ECN Energy Research Centre of the Netherlands
- DUWIND Delft University Wind Energy Research Institute

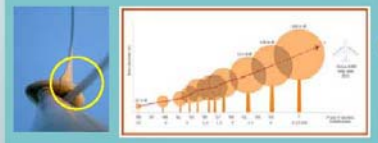
➢ Nodal point
- National partner

European Academy of Wind Energy

R&D areas

Resource assessment

Concepts

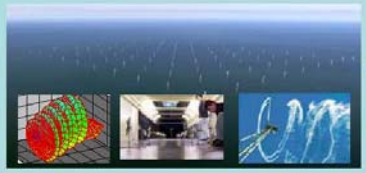


Rotor Aerodynamics
Aero-elastics
Aero-acoustics

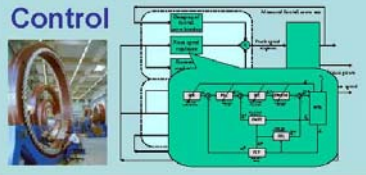
Components

Structural dynamics

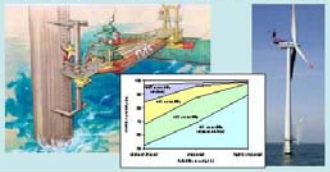
Wake interference



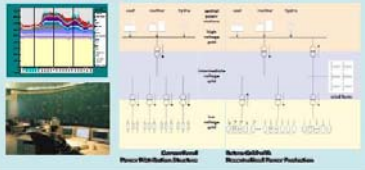
Electrical conversion & Control



Operation & Maintenance



Grid integration



Environment, Nature, Risks, Social acceptance, Value

Research and Development Routes

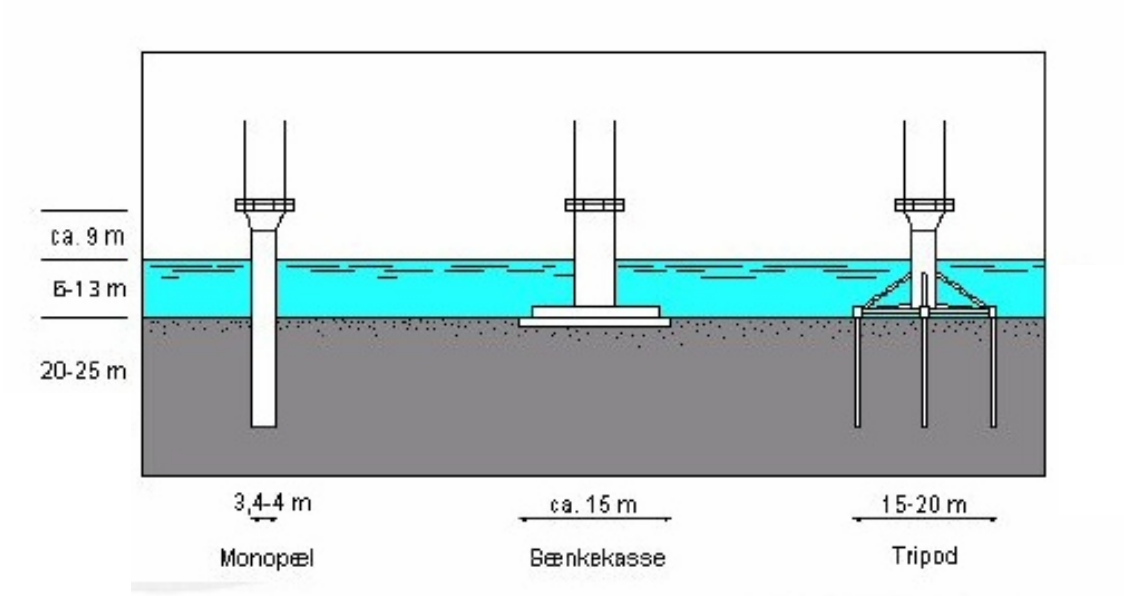
- Concepts and components
- Rotor aero-elastics and structural dynamics
- Grid integration and control
- Resource assessment, wake interference and design winds
- Tests and measurements

Concepts and components

Offshore is the technology driver

Horns Rev 160 MW

Example: Foundation concepts



Water depth (m)	Concepts for wind turbine structure
0-10	Gravity based type
0-30	Mono pile type
> 20	Tripod / jacket type
> 50	Floating type

State-of-the-art design and trends

Issue	State of the art	Future trends
Size	D = 120 m H = 100 m P = 5 MW	D = 160 m H = 120 – 140 m P = 10 MW
O&M cost over lifetime	Costs correspond to up to approximately 50% of initial investment	Halving
Water depth	5 - 20 m	50 meter 200 m (floating structures)
Foundation types	Gravity, mono-piles	Gravity, mono piles, suction bucket, tripods, floating platforms
Rotor Tip speed	60 – 80 m/s	80 – 120 m/s
Acoustic noise	Limited by tip speed	Limited by active control
Structural design	Passive	Actively controlled for lower loads
Materials	Chosen for strength	Function, economy and LCA (Life Cycle Analysis)
Control system	Separate WTG, Park	Combined, wind power plant
Production forecast	Market requirement is 12 – 36 hours	Market requirement is 12 – 36 hours
Production strategy	Maximum energy	Maximum revenue
Price of wind electricity	Various support schemes and compensation for CO_2	Market price
Grid	National grid	International, island operation, storage
Transmission	AC	HVDC

Rotor aero-elastics and structural dynamics

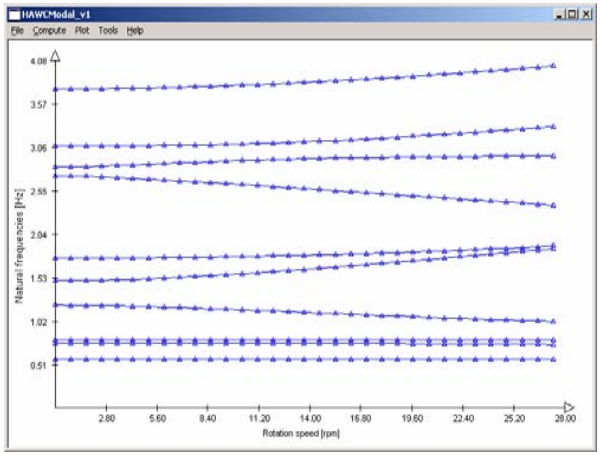
Aerodynamics for wind turbines

RISØ

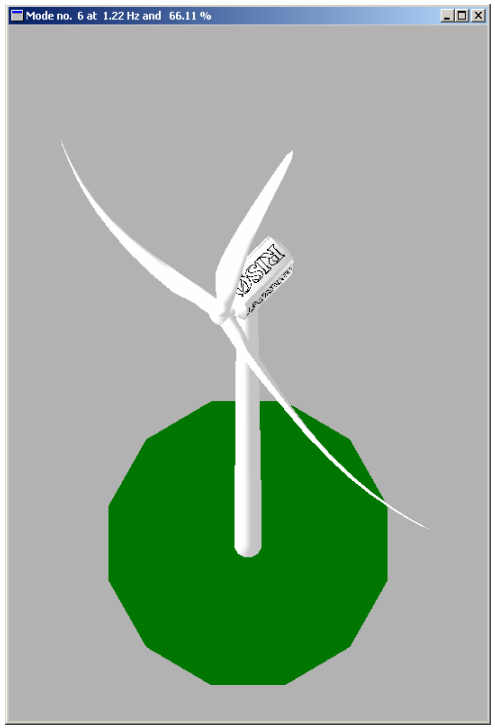
- Flow over complex terrain
- Rotor aerodynamics
- Rotor/Tower interaction
- Wake aerodynamics
- Airfoil Flows
- Laminar/turbulent transition
- Hysteresis phenomena, dynamic stall
- Damping and stability
- Aeroelasticity

Aeroelastic tools

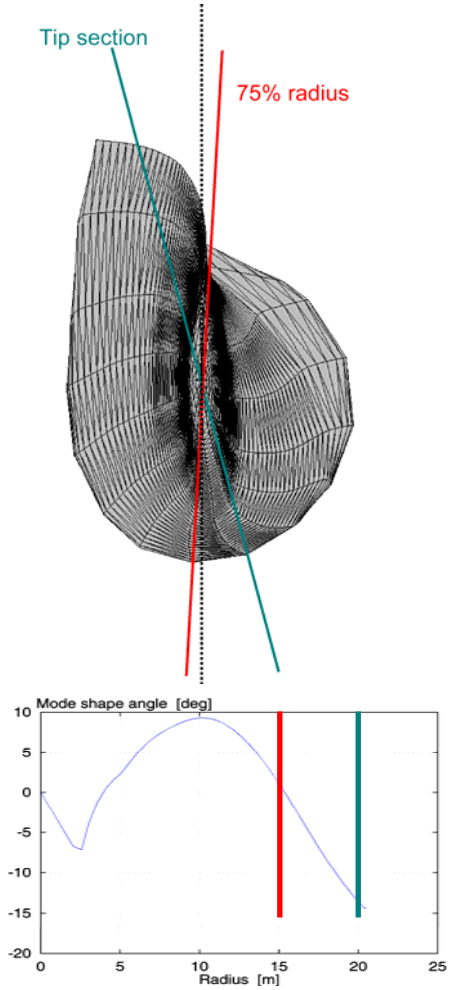
- **HAWC**
- **HAWCStab**
- **HAWCModal**
- **HAWCDamp**



Cambell diagram



Deflected turbine
during operation

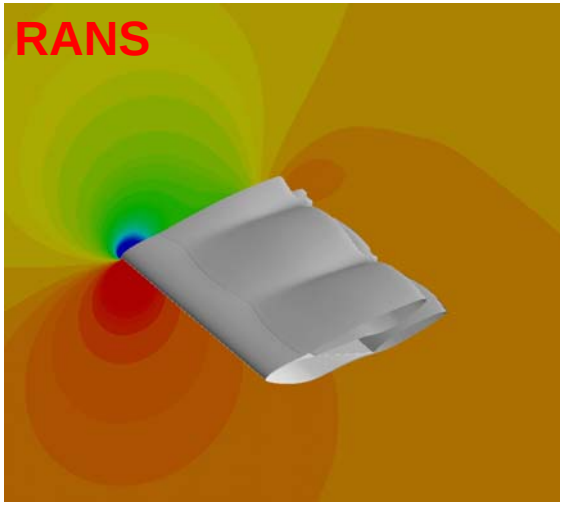


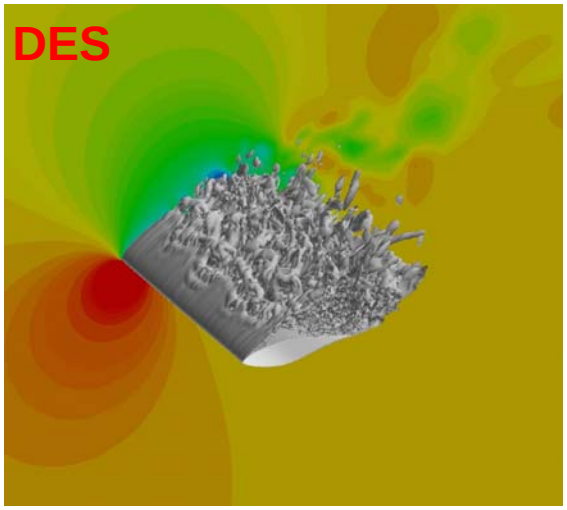
Direction of vibration

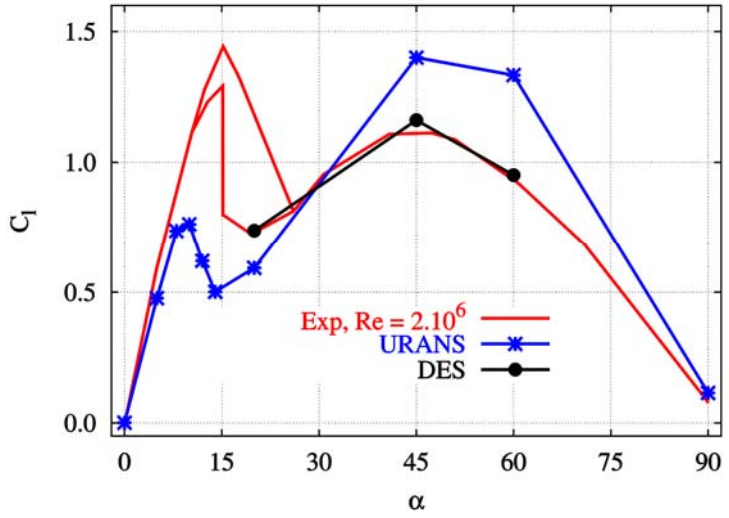
CFD modelling of wind turbines

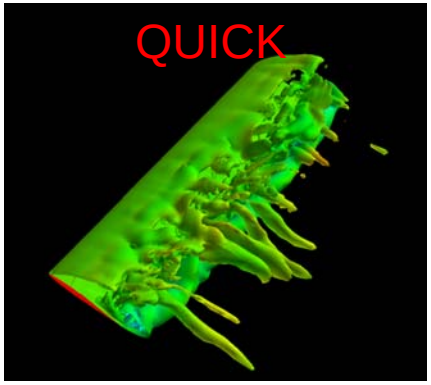
e.g. Deep stall aerodynamics

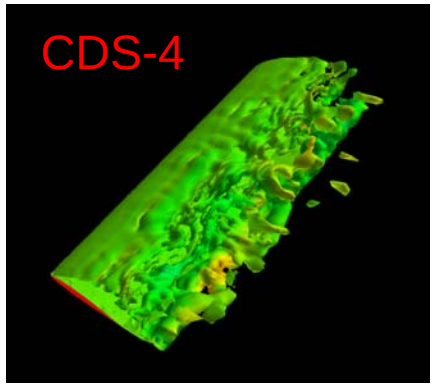
RISØ





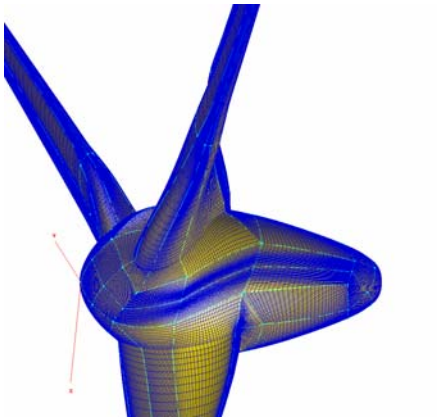


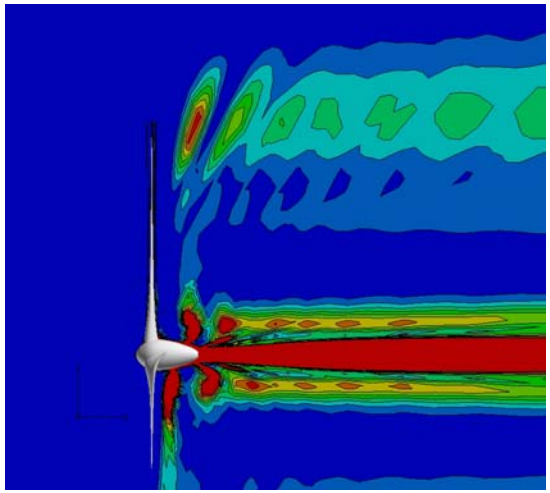




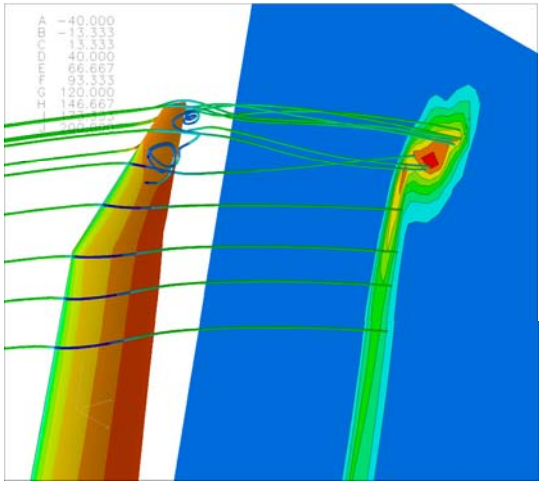
Vorticity iso-surface around the 809 airfoil

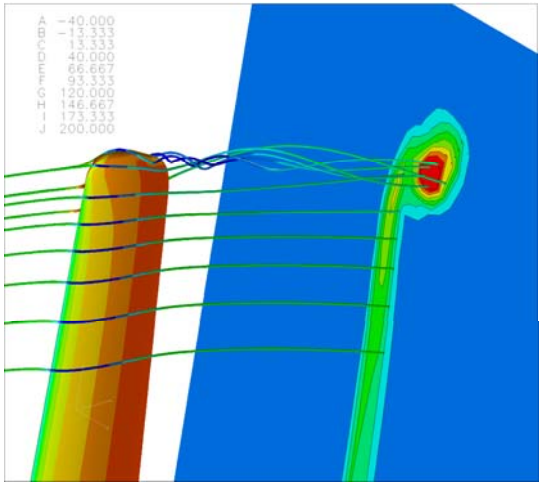
Detailed design analysis



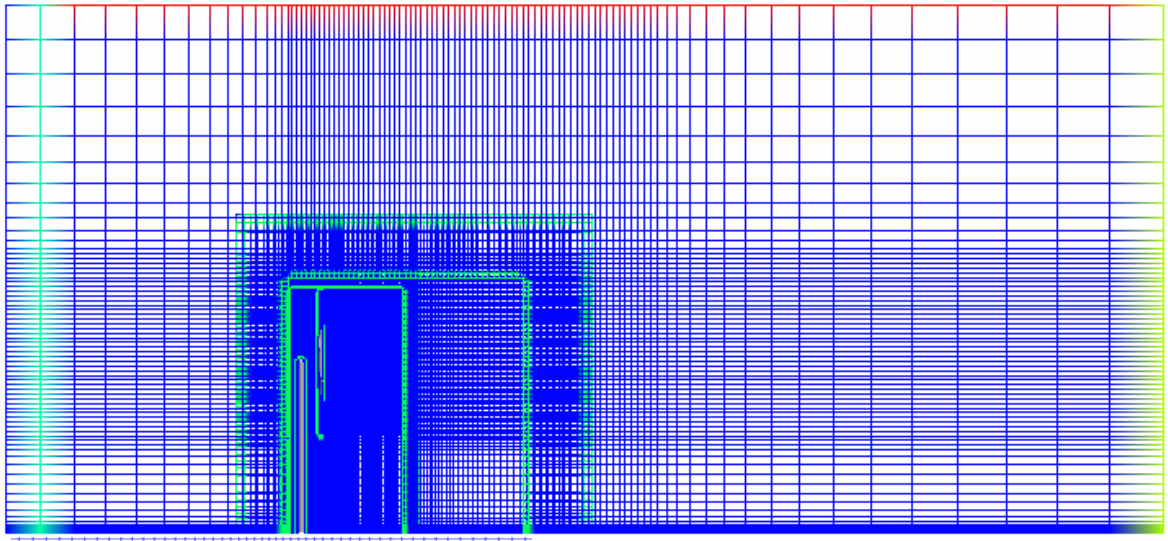


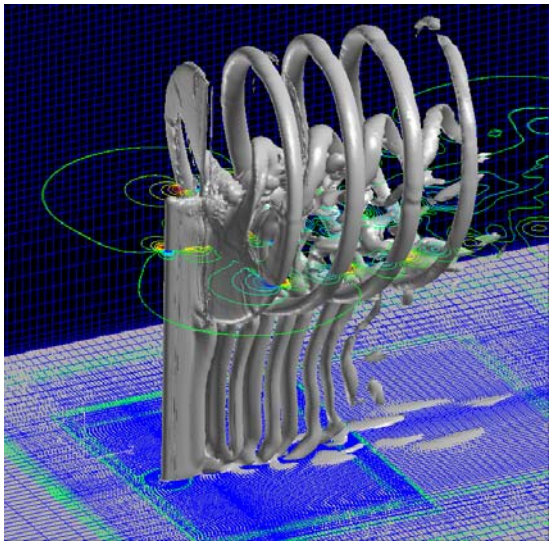
Tip-design

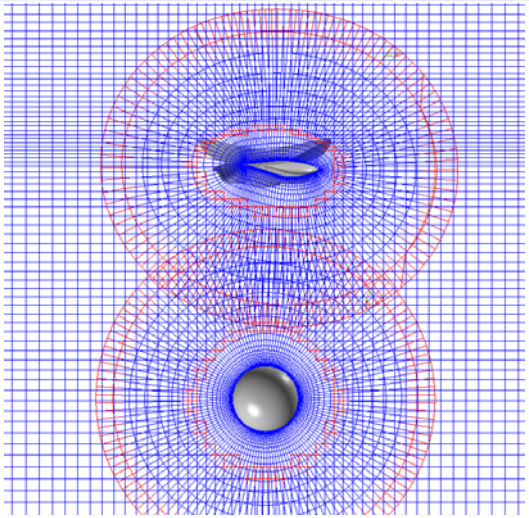


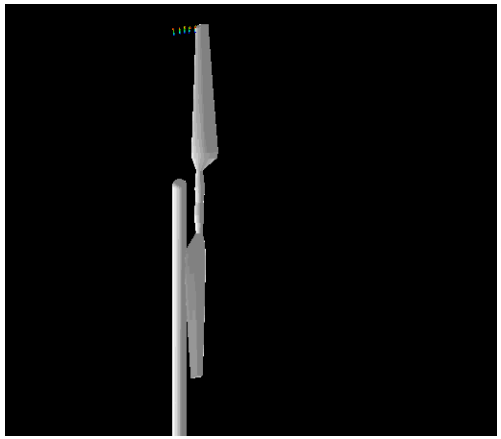


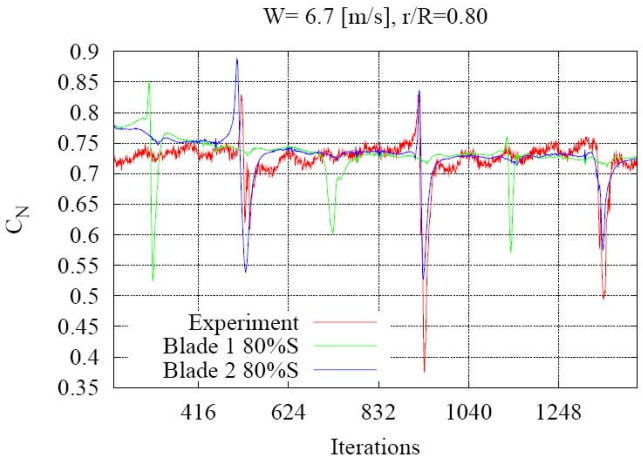
Rotor/tower interaction





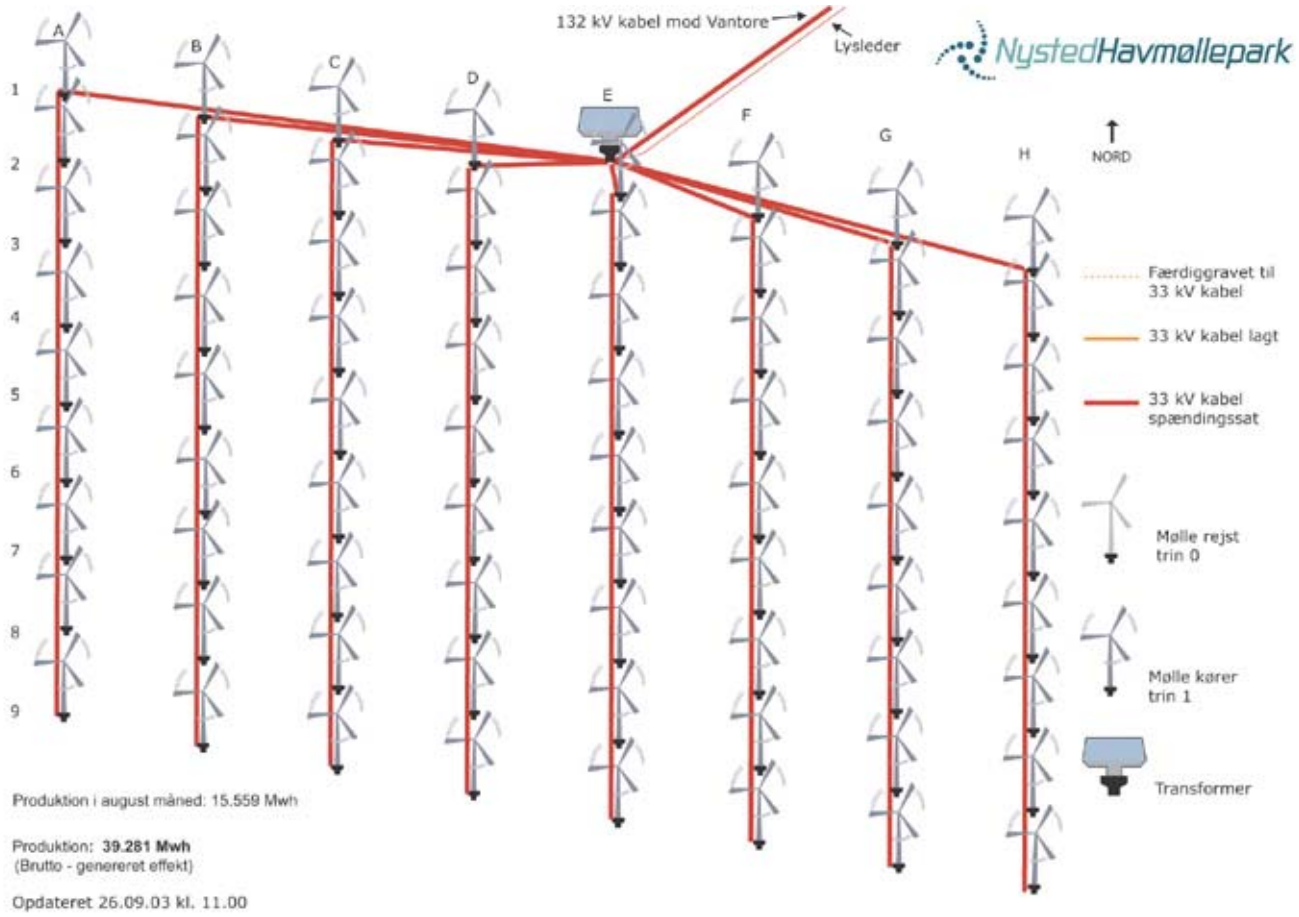




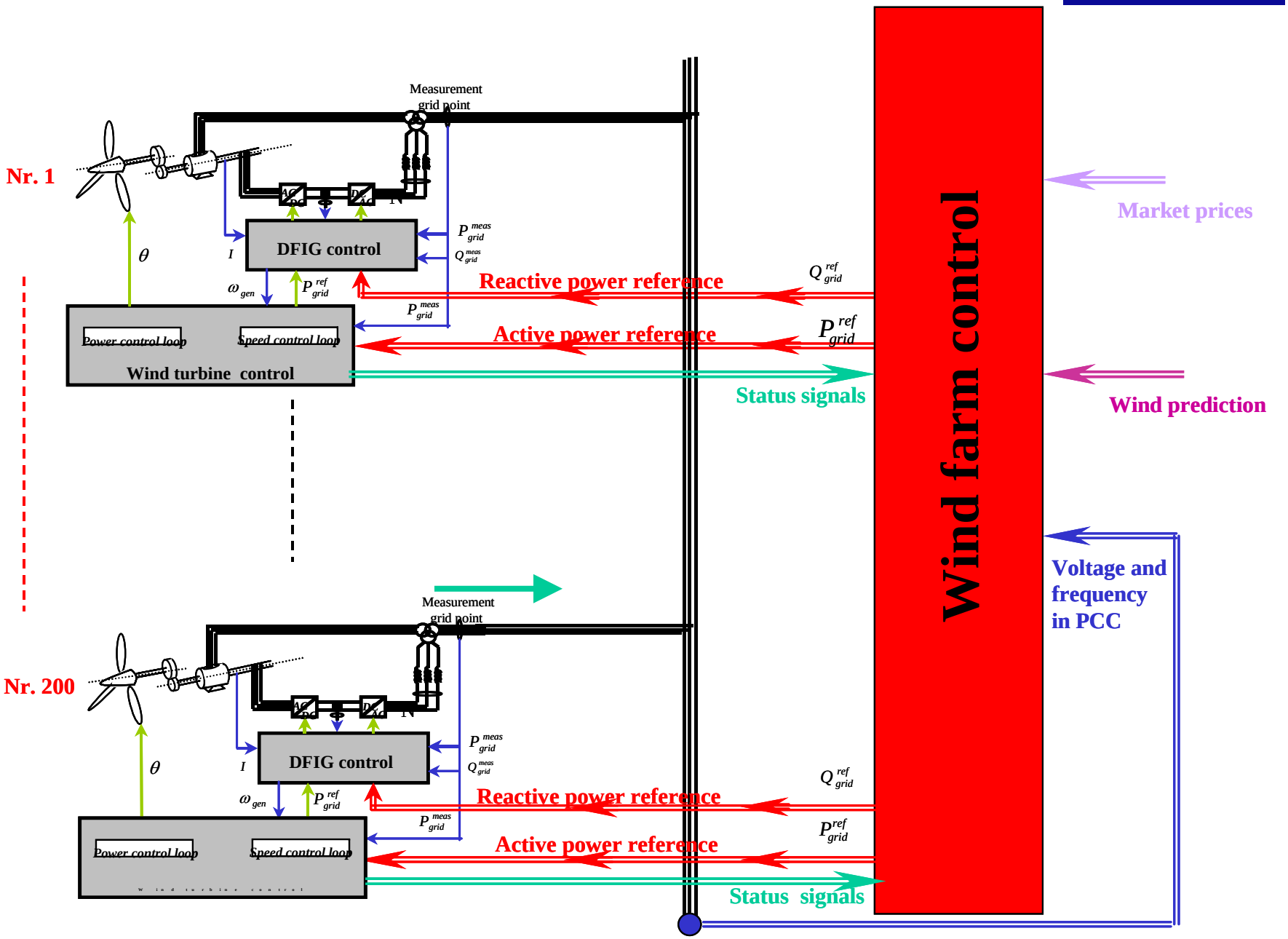


Grid integration and control

Grid Connections at Nysted wind farm - 165.6 MW

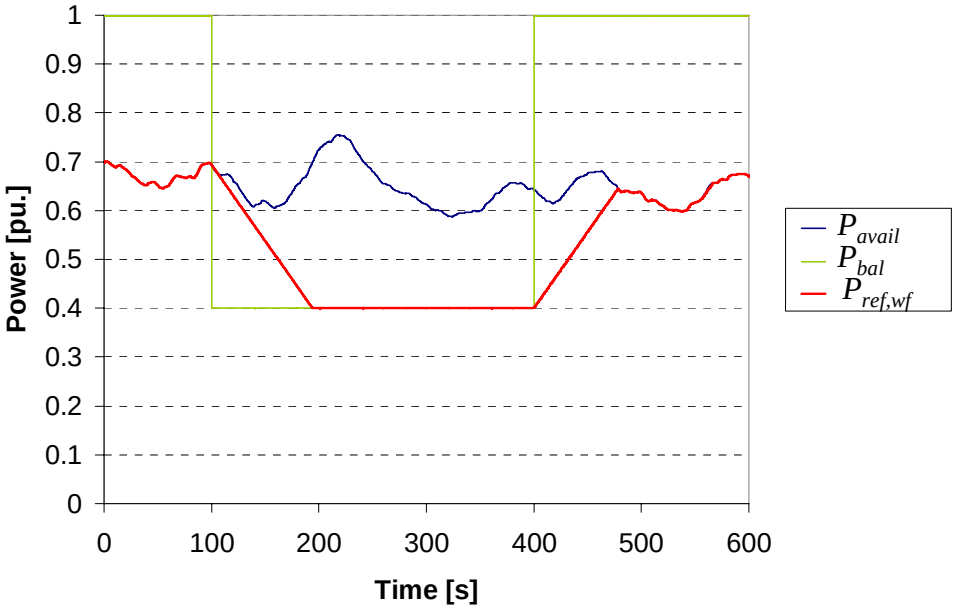


Wind farm controls as wind power plants

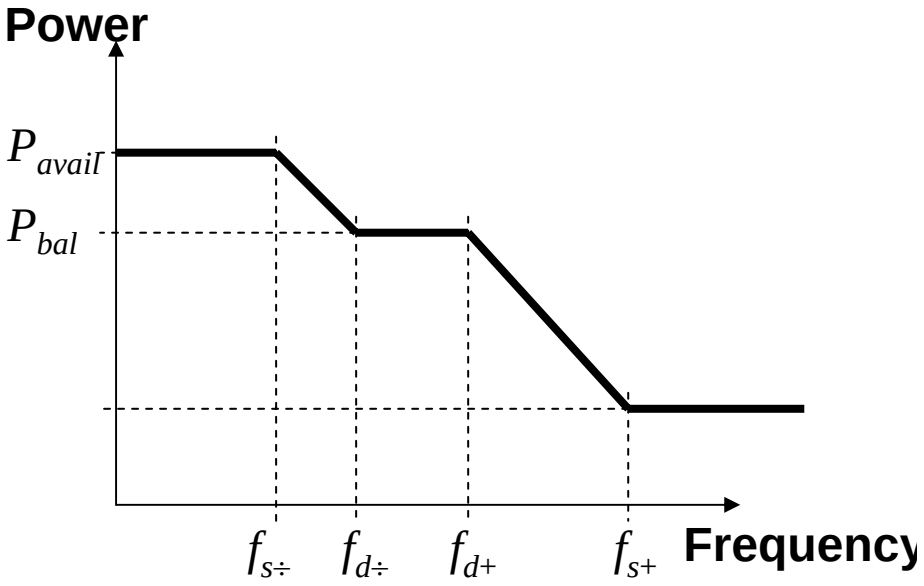


Balance control

- **Balance control provides**
- **Balance control already implemented in Horns Rev**



- **Reserve can be utilised in frequency control (droop and deadband)**

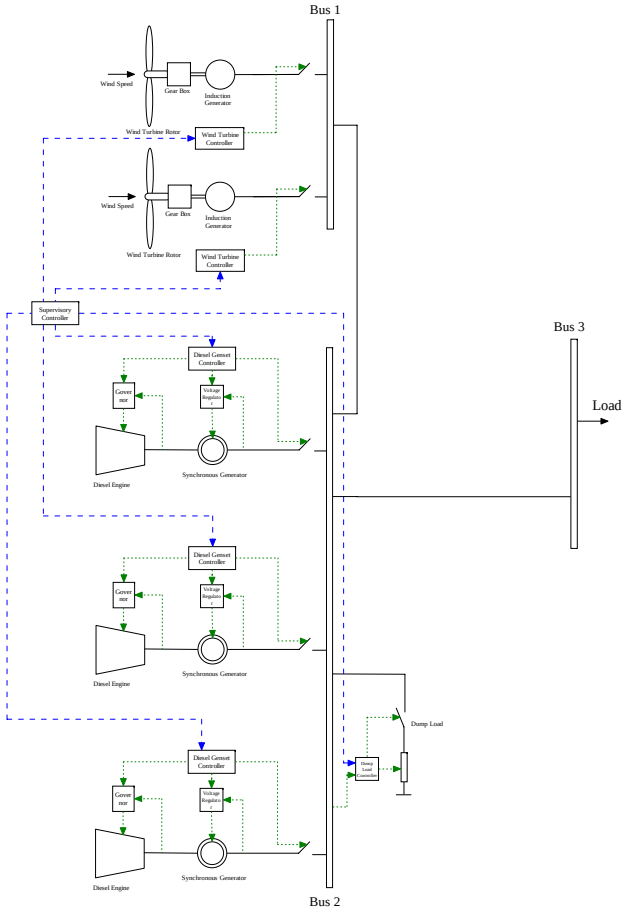


Simulation of Energy Systems
Integration of large penetration of RE

Modelling of complete energy systems

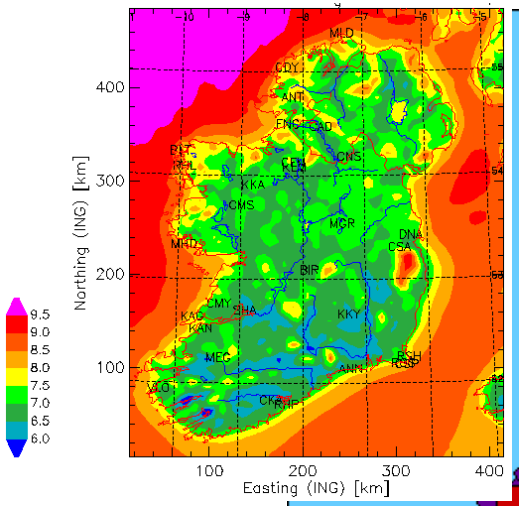
- Large RE-input, generators, loads, storage, thermal and other bindings
- Flexible configuration, spatial distribution
- Bottlenecks in transmission
- Power quality and stability
- Control systems, distributed intelligence, communication

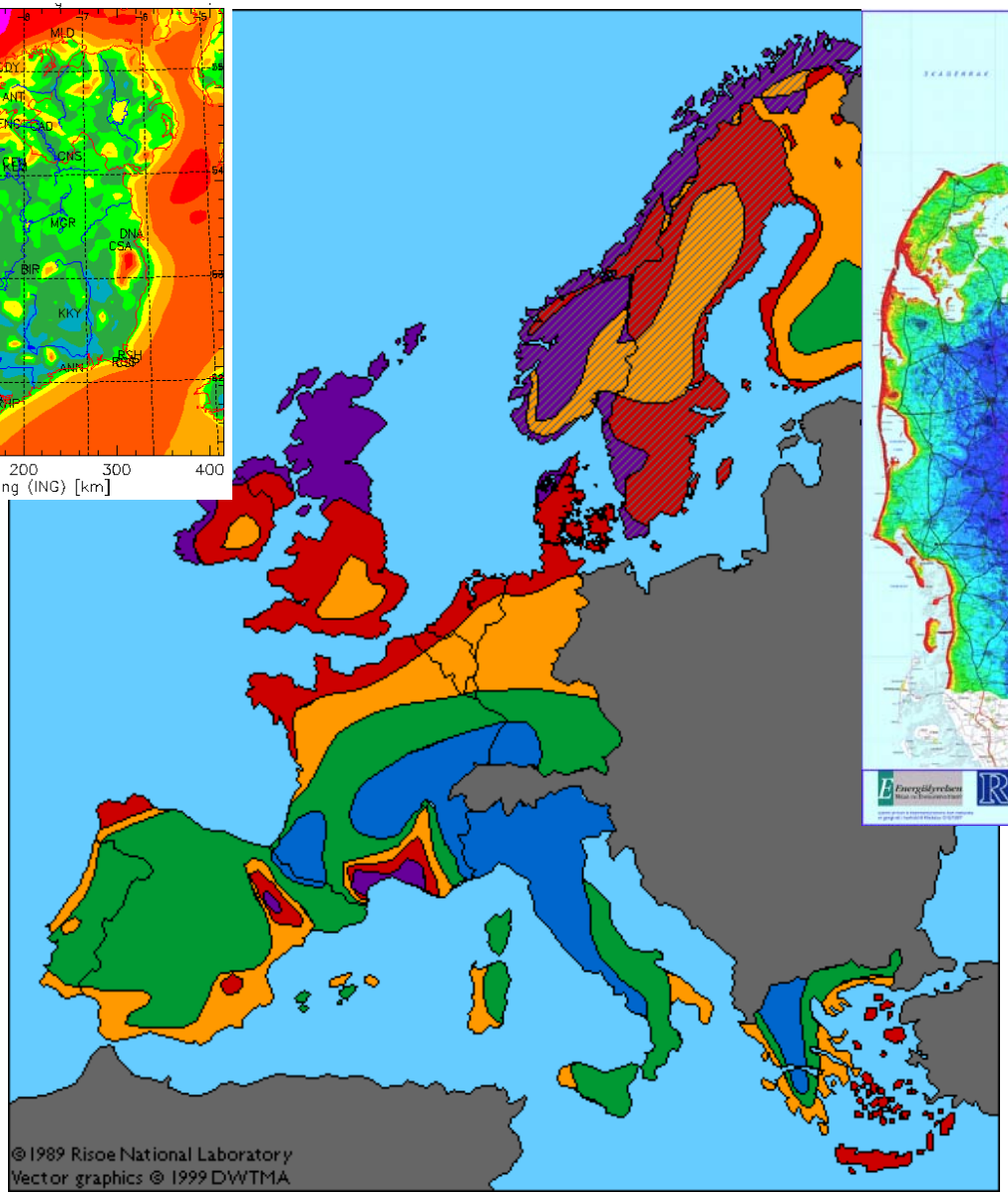
IPSYS

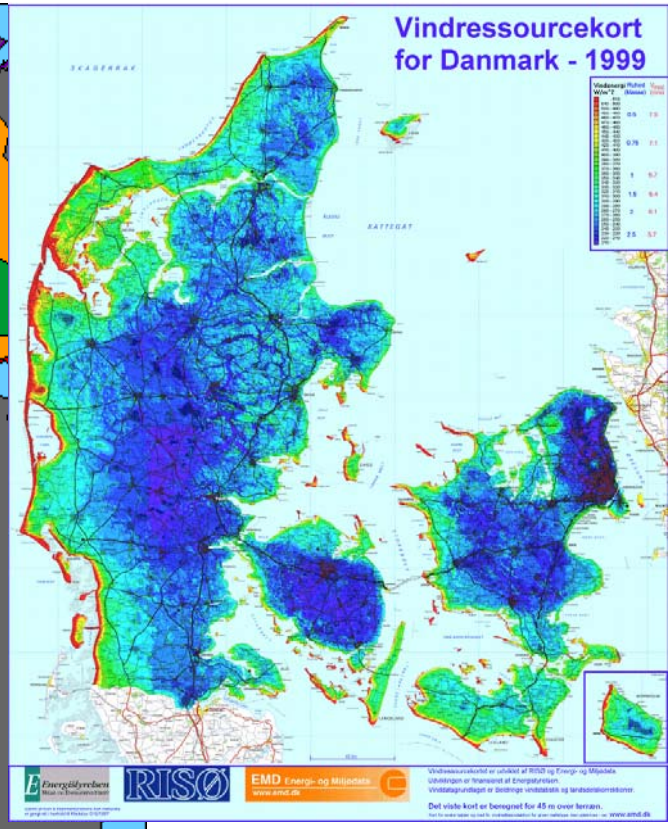


Resource assessment, wake interference and design winds

Resources: Wind Atlases



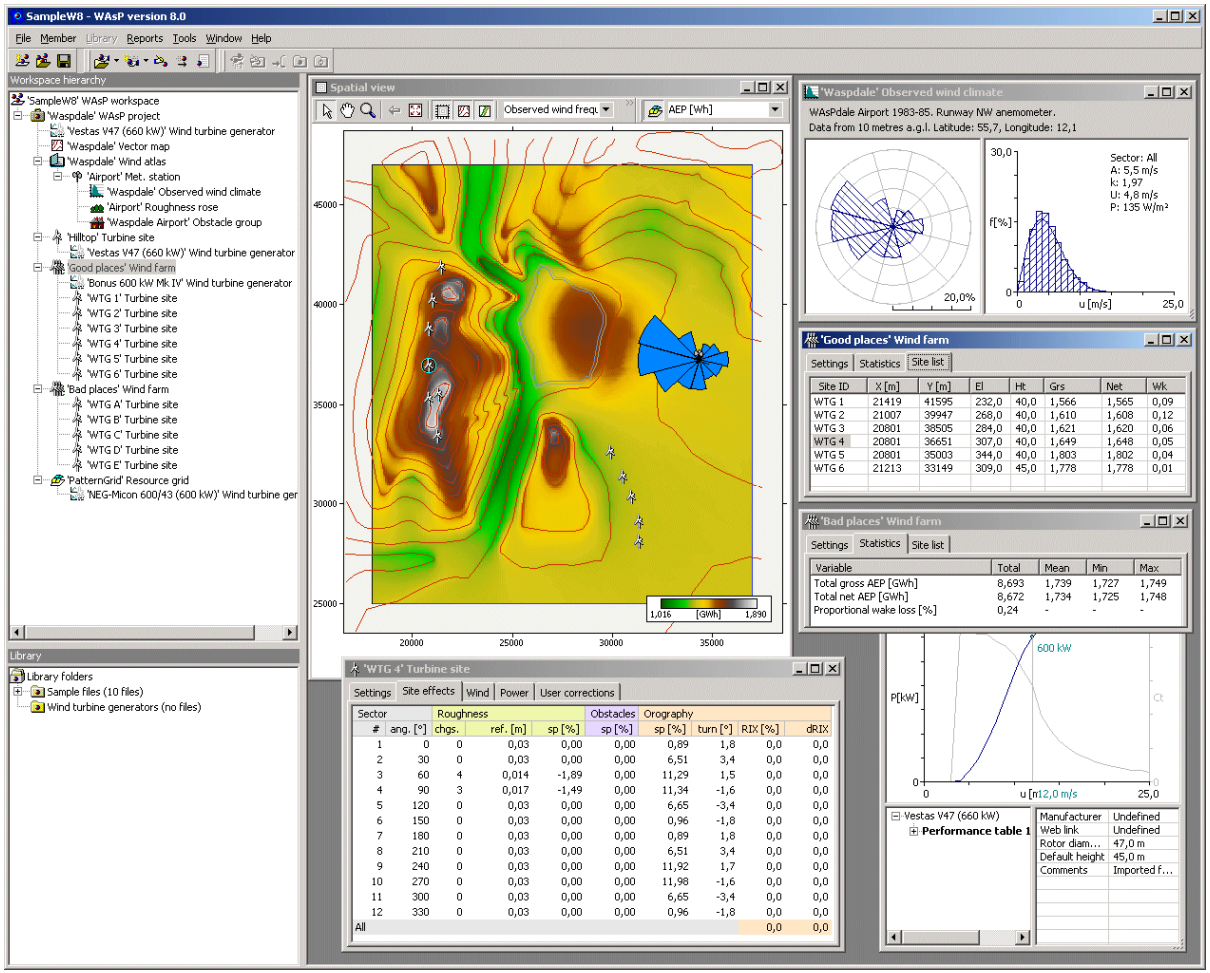




Links

- www.wasp.dk
- www.waspengineering.dk
- www.windatlas.dk
- www.mesoscale.dk
- www.prediktor.dk
- www.risoe.dk
- www.risoe.dk/vea
- www.risoe.dk/vea-data

WAsP
wind resources, production estimation and siting



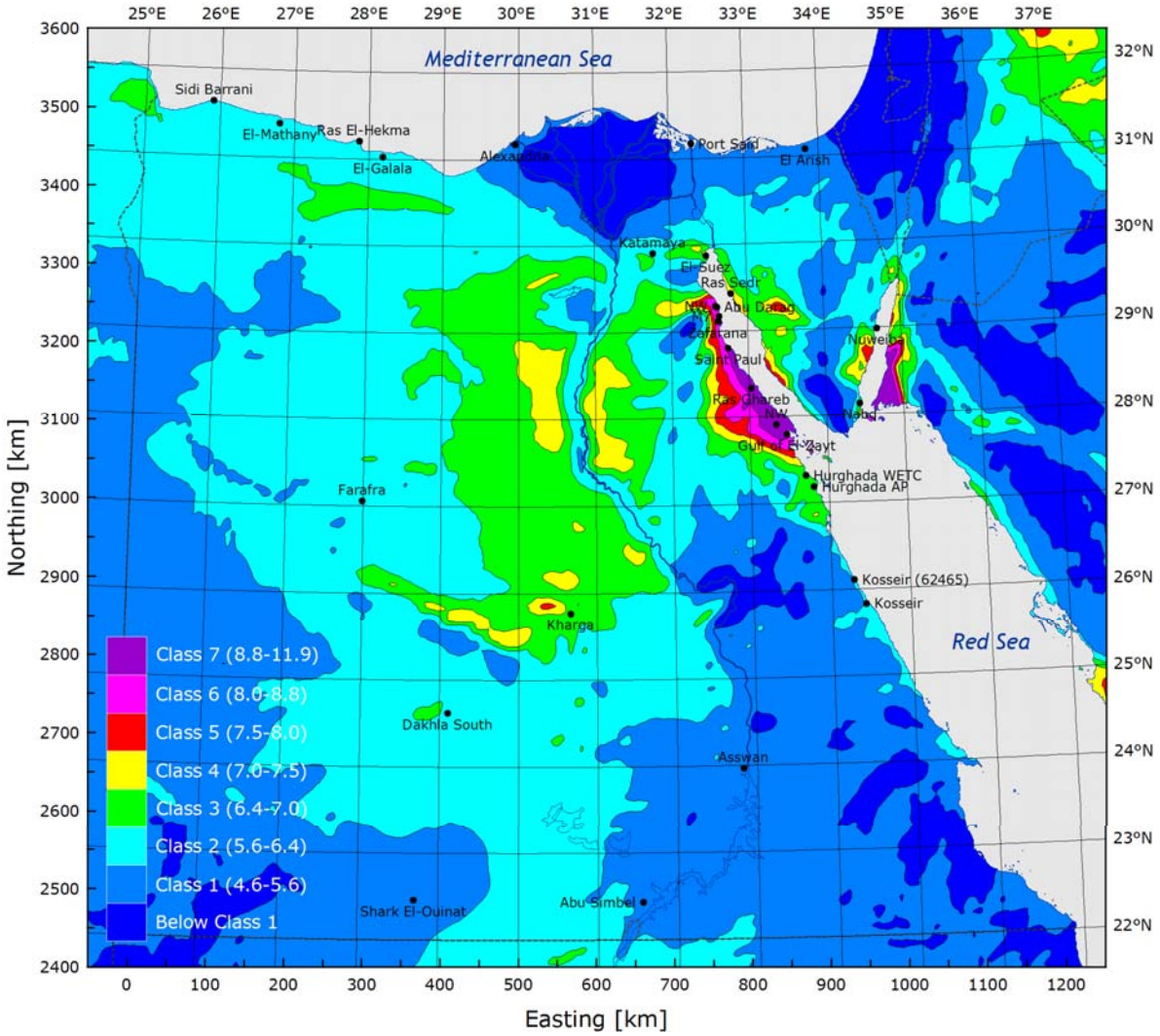
The industry-standard Wind Atlas Analysis and Application Program

More than 1700 users in over 100 countries use WAsP for:

- **Wind data analysis**
- **Map digitisation & editing**
- **Wind atlas generation**
- **Wind climate estimation**
- **Power production of WTG's**
- **Micro-siting of wind turbines**
- **Wind farm production**
- **Wind farm efficiency**
- **Wind resource mapping**

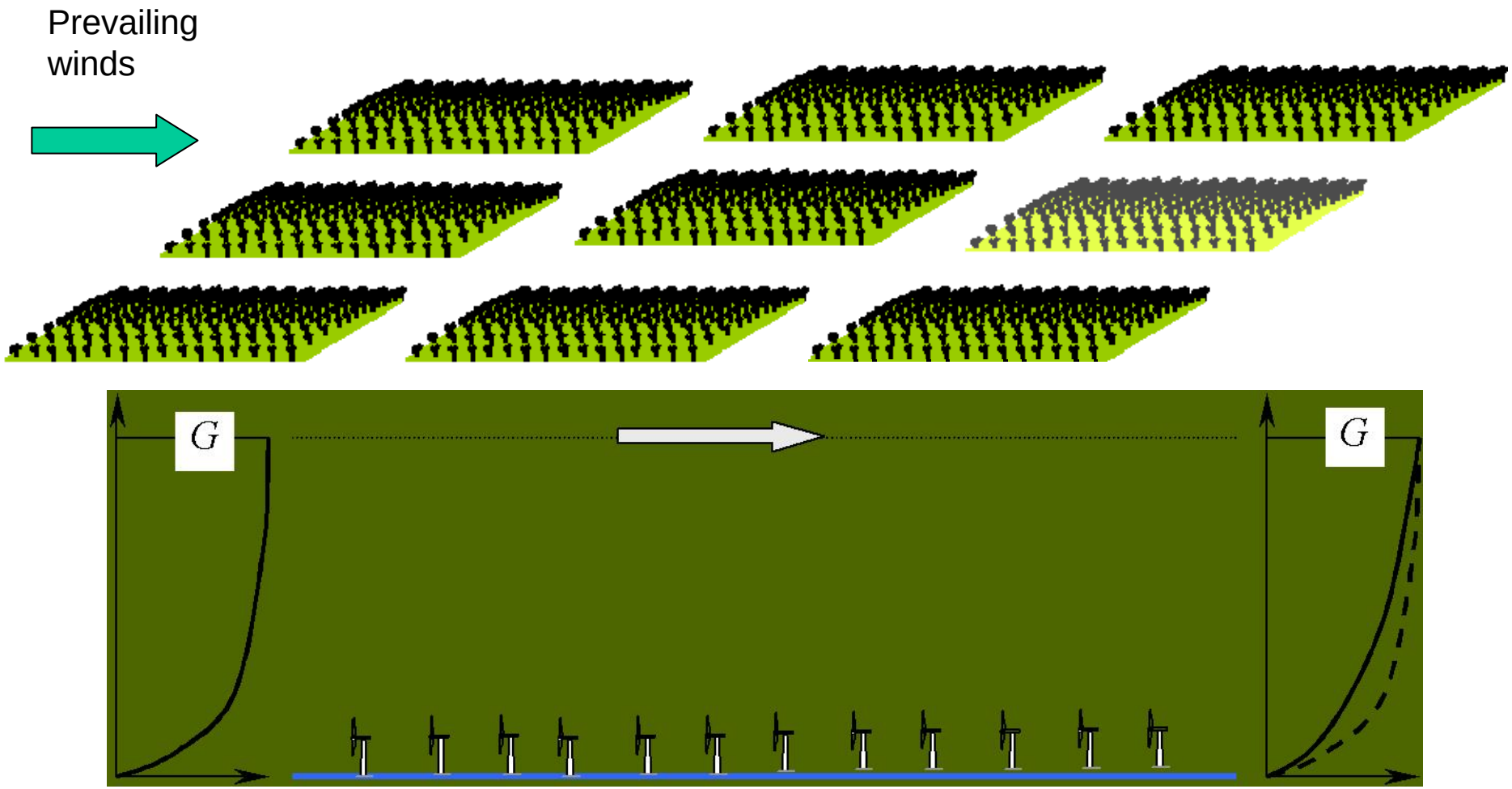
Wind Atlas for Egypt

New wind resource maps



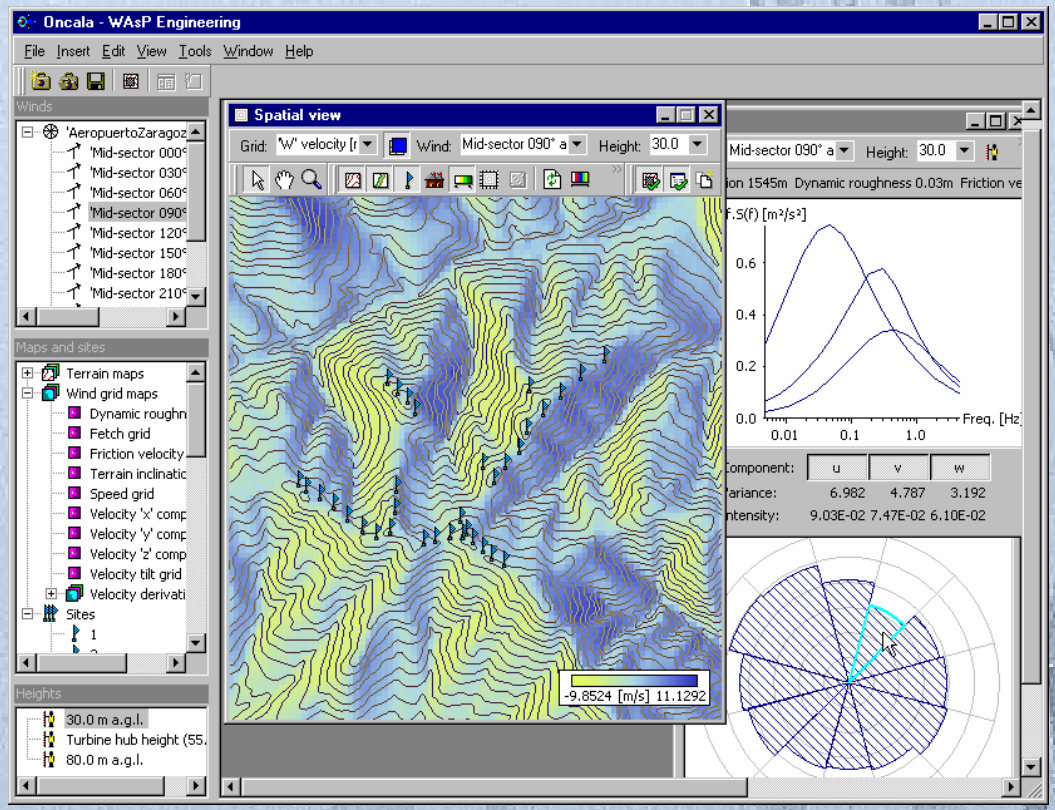
- **Predicted wind climate**
- **Mean wind speed 50 m a.g.l. [ms^{-1}]**
- **7 speed classes**
- **KAMM modelling**
- **Resolution 7.5 km**
- **NCEP/NCAR data**
- **SRTM30 elevation**
- **GLCC land cover**
- **Terrain features may give higher wind speeds locally!**
- **Output formats:**
  - map graphics
  - statistics. …

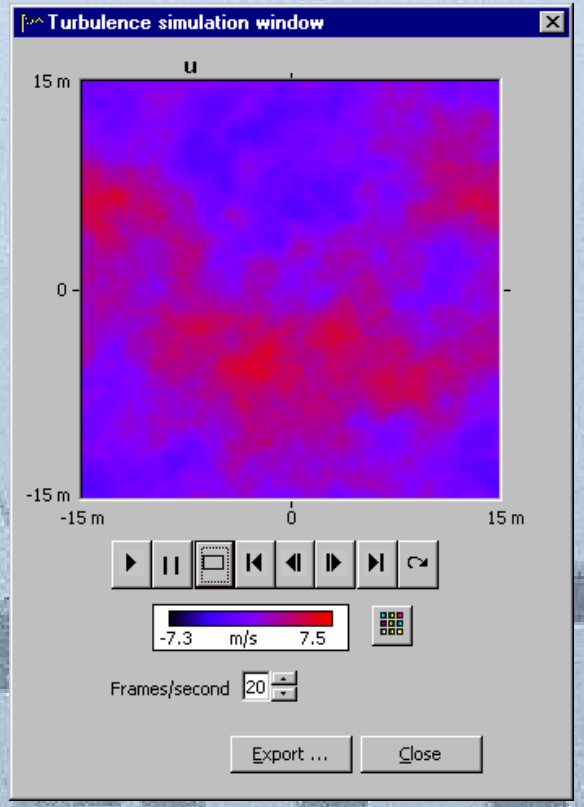
Flow in large-scale wind farms



WAsP Engineering

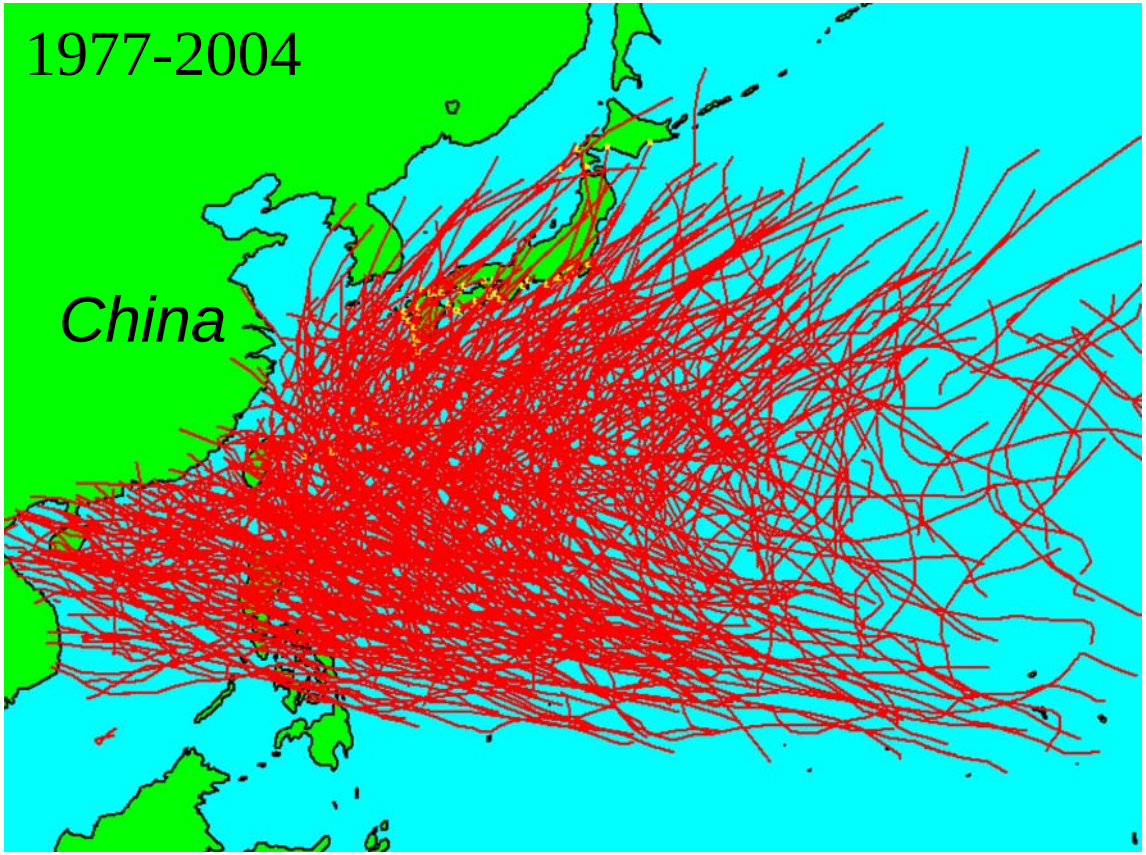
Modelling of design wind conditions

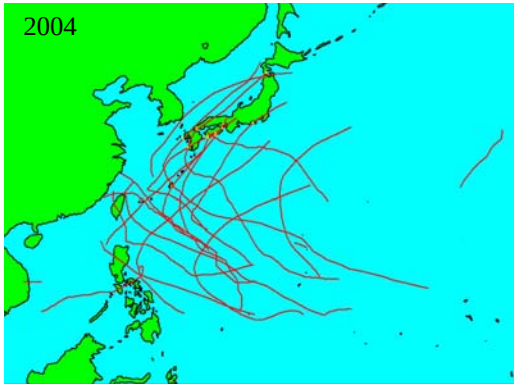




Tropical Cyclones

Typhoon tracks

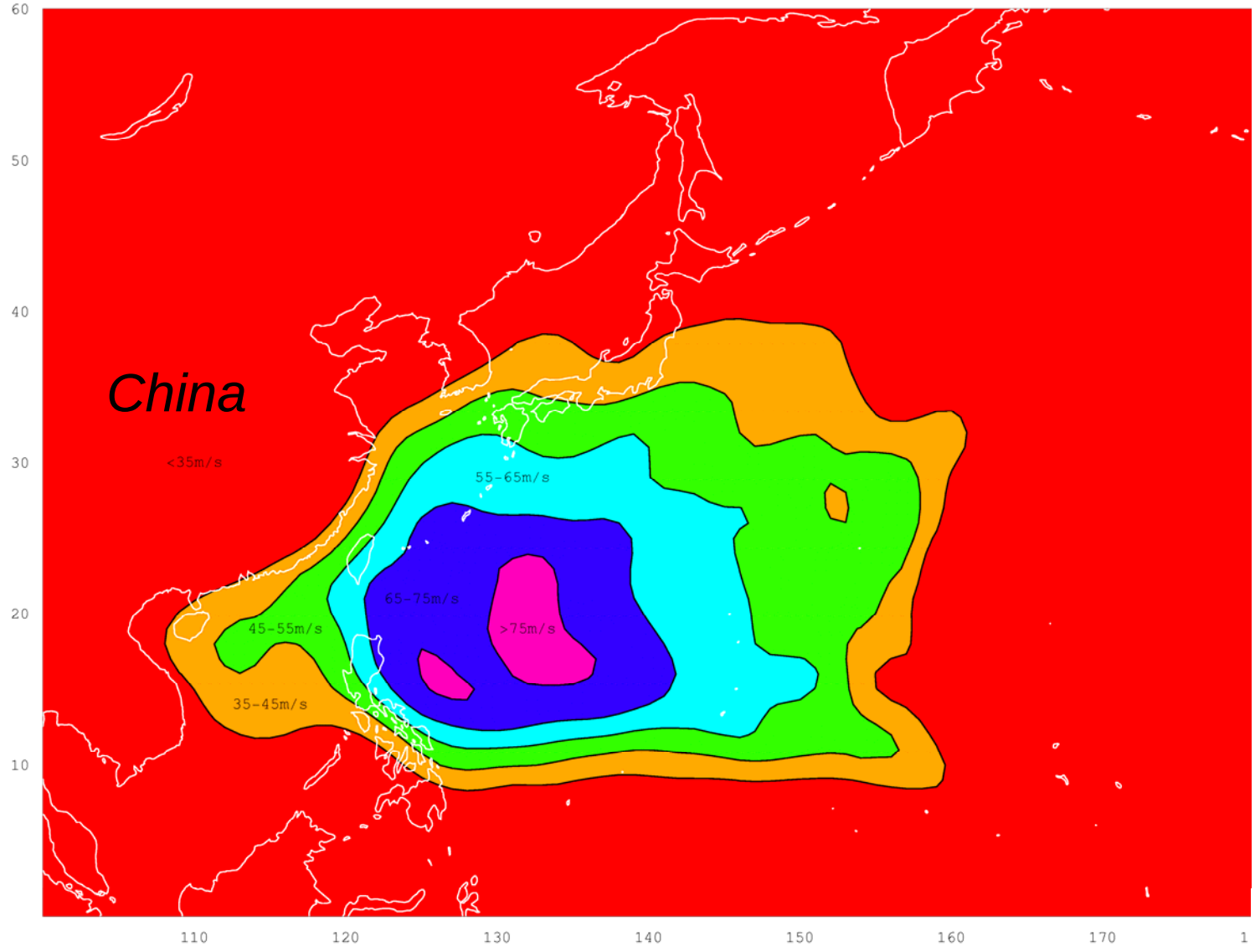




Parts of tracks with V_{max} > 50 knots shown

Tropical Cyclones

NW Pacific extreme wind atlas



Tests and measurements

Test Station for Large Wind Turbines at Høvsøre

Test Station for Large Wind Turbines at Høvsøre

RISØ

Remote Sensing Technologies – SODAR & LIDAR

SODAR = SOund Detection And Ranging
LIDAR = LIght Detection And Ranging

Measurements, sensor technology, data collection

UPWIND
the largest EU wind energy research project

- **Main objective: cost optimisation of the future types of large wind turbines (10-20MW)**
- **39 partners (coordinated by Risø), 23 mio Euro (EU support: 14.3 mio Euro), 5 years**
- **Integration of research with industry**

  design and standards, metrology, fiberblades, transmission/conversion, smart rotor blades and upscaling as well as aiming at,

- **Research topics**
  - Aerodynamics & aeroelastics
  - Rotor structure and materials
  - Foundations and support structure
  - control systems
  - remote sensing
  - flow
  - electrical grid

DANISH WIND INDUSTRY ASSOCIATION
www.windpower.org

Denmark is Wind Power Hub

123 members

home of half of the wind turbine industry for decades,
including a large number of sub-suppliers, contractors and consultants